33.5 A 100mW Dual-Band CMOS Mobile-TV Tuner IC for T-DMB/DAB and ISDB-T

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Since the kick-off of the Satellite DMB service in Korea and Japan, terrestrial broadcasting standards such as T-DMB in Korea, China, and Europe, DVB-H in Europe and US, and ISDB-T in Japan (1-segment and 3-segment) are struggling to take over the market within their own region. With the technology of satellite and terrestrial mobile broadcasting service becoming available world-wide, the future mobile device will be able to provide high-quality digital broadcasting to the consumers; and will be the next-generation "killer application".

In this paper, a CMOS dual-band low-IF mobile-TV tuner IC for T-DMB/DAB that supports band-III and L-band is described. With minor modifications, such as changing few metal and via masks, this IC supports VHF and UHF bands for ISDB-T partial reception. Therefore, with this approach, mask price can be reduced for small feature-size CMOS processes, and lead time can be minimized for various applications. This chip meets all specifications for both applications with low power consumption of 100mW from a 1.8V supply.

Figure 33.5.1 shows the comparison table of T-DMB/DAB and ISDB-T partial reception. Most of T-DMB specifications are from Eureka-147 which is a DAB standard in Europe. Because of relatively wide bandwidth of 1.536MHz, this standard is modified for mobile video broadcasting in Korea. ISDB-T is Japanese digital-TV standard, and it specifies not only fine-resolution full-segment broadcasting for home-TV but also partial (1- and 3-segment) transmission/reception with small data rates for mobile applications. As shown in Fig. 33.5.1, T-DMB and ISDB-T tuners can be switched by adjusting the RF input frequency band and the low-pass filter cutoff frequency. This factor has been reflected in the chip design, in order to develop a tuner IC supporting T-DMB and ISDB-T with minimum change in metal masks.

Figure 33.5.2 shows block diagram of the dual-band tuner IC. There are two RF inputs which are band-III/L-band for T-DMB and VHF/UHF for ISDB-T application. L-band RF amplifiers and mixers can be switched to UHF-band using a few metal and via layers. Both LNAs have high and low gain modes which are controlled by RF AGC block. After LNA, RF PGA block amplifies or attenuates RF signals [1] with a fine gain step of 0.25dB. To increase RF dynamic range, it is better to attenuate RF signal before active devices when the input of the IC is a large RF signal. The fine gain step at the RF stage helps to get constant output SNR independent of RF input power. By virtue of fine-gain-step high-dynamic-range (50dB) RF PGA, output SNR of this tuner IC is constant over a 50dB range as shown in the Fig. 33.5.3. This means that the SNR and linearity performance such as adjacent-channel-rejection ratio (ACR) are almost constant over a wide RF input power range with a small power consumption.

AGC scheme of this tuner is shown in the Fig. 33.5.2. There are three RSSIs which are composed of wide-band RF power detector in front of the mixer (RF PDET), narrow-band RSSI for RF AGC (RF RSSI) between the low-pass filter and the IF VGA, and another narrow-band RSSI for IF output (IF RSSI). RF RSSI detects wanted channel power after channel selection, and determines RF gain which is comprised of gain-switching LNA and RF PGA. RF AGC determines the output SNR and linearity at some RF input. As described above, fine-step RF PGA shows constant SNR and immunity to interferer for wide range of RF input power. IF RSSI detects final IF output and controls IF gain via IF VGA. RF PDET adjusts RF gain only when high RF power comes into RF blocks. In this case, this block reduces RF gain by compromising output SNR of wanted channel.

Figure 33.5.4 shows circuit diagram of RFPGA [1]. In the first gain attenuation, in order to attain a wide gain range, a resistive attenuator is used. Combined configuration of common-source and common-gate amplifier in the first amplifier converts single-ended input to differential output as shown in Fig. 33.5.4(A). The second amplifier uses differential multiple-gated transistor (DMGTR) for linearity enhancement and the last amplifier uses source-follower step gain amplifier. The preceding stage gain step is covered by following stage total gain range, thus it comprises 50dB gain range with quasi-continuous (0.25dB/bit) resolution.

The most stringent specification of T-DMB is digital ACR. The minimum requirement is 30dB for the narrow guard band of 192kHz, whereas conventional heterodyne tuners can already achieve around 35dB ACR by virtue of the sharp skirt characteristic of IF SAW filter. For low-IF tuner, low-pass filter and image-rejection mixer characteristics determine this performance. To achieve this performance, an 8^{th}-order elliptic active-RC filter [2] and double quadrature passive image-rejection mixer with 7-stage IF poly-phase filter [3] are designed. The low-pass filter shows 60dB attenuation @ 2.4MHz with cutoff frequency of 1.6MHz. The image-rejection ratio of the mixer is typically 56dB, which is sufficient for 35dB ACR. Figure 33.5.5 shows the tuner IF response as compared with commercial IF SAW filter centered at 38.912MHz. As shown in the figure, this cutoff characteristic of this tuner is better than that of the commercial SAW filter. With proper demodulator IC, the ACR of the tuner is over 40dB for both of N+1 and N-1 digital adjacent channels, which is superior to the conventional heterodyne tuners using bulky IF SAW filter. Since ACR strongly depends on cutoff frequency variation of the low-pass filter, cutoff-tuning circuit is implemented [2] and it shows ±1.5% tuning error, low enough for mass production.

This chip is fabricated in a 1P 6M 0.18μm CMOS process and is packaged in a 6mm×6mm 40-pin QFN. From field test results, this tuner shows better performance than conventional heterodyne receiver for T-DMB in Korea, band-III/L-band DAB in Germany and England, and ISDB-T in Japan.

Figure 33.5.6 shows the performance summary of the IC. The performance meets all the specifications for both of T-DMB and ISDB-T. Figure 33.5.7 shows the micrograph of the chip that occupies a total area of $3.4\times3.3mm^2$.

References:

[1] T. Kim et al., "A 13 dB IIP3 Improved Low-Power CMOS RF Programmable Gain Amplifier using Differential Circuit Transconductance Linearization for Various Terrestrial Mobile D-TV Applications," *Symp. VLSI Circuits,* pp. 344-347, June, 2005.

[2] S. Kim et al., "A 43 dB ACR Low-Pass Filter with Automatic Tuning for Low-IF Conversion DAB/T-DMB Tuner IC," *ESSCIRC,* pp. 319-322, Sept., 2005.

[3] Y. Cho et al., "A CMOS Image Rejection Mixer for DAB/DMB Low-IF Tuner IC Exhibiting 41dB Adjacent Channel Rejection Ratio," *Asian Solid-State Circuits Conf*., pp. 461-464, Nov., 2005.

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	T-DMB/DAB		ISDB-T	
RF frequency (MHz)	Band-III	174 ~ 245	VHF	90 ~ 222
	L-band	1450 ~ 1492	UHF	470 ~ 770
Signal bandwidth (MHz)	1.536		1-seg	0.43
			3-seg	1.29
Modulation	COFDM (DQPSK)		COFDM (QPSK, 16-QAM)	
Required C/N (dB)	7		QPSK	4.9
			16-QAM	11.5

Figure 33.5.1: Comparison table of T-DMB/DAB and ISDB-T standards.

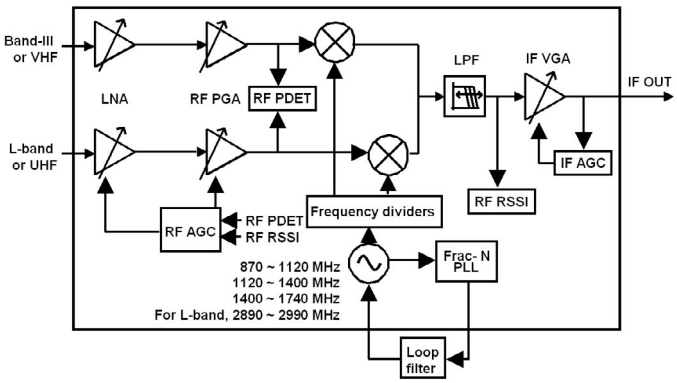

Figure 33.5.2: Block diagram of the tuner IC.

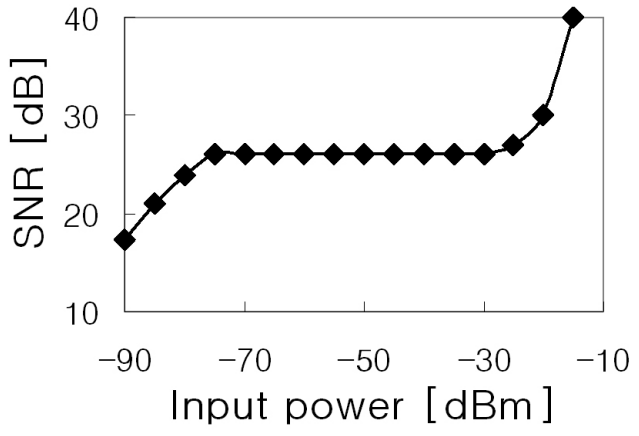

Figure 33.5.3: Output SNR versus RF input power of the tuner IC.

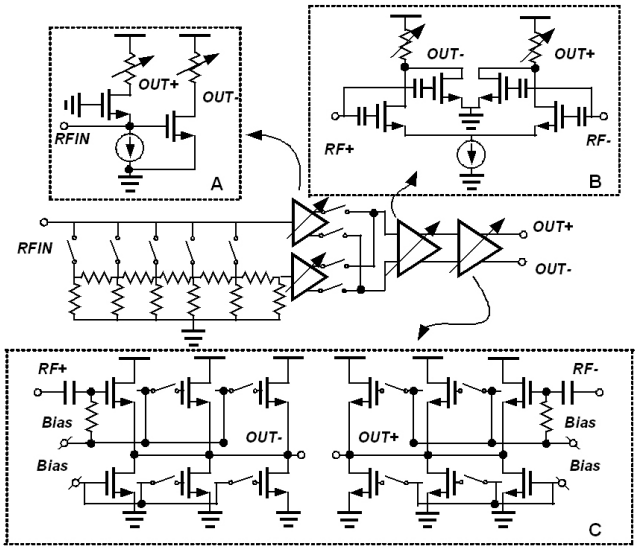

Figure 33.5.4: Circuit diagram of RF PGA.

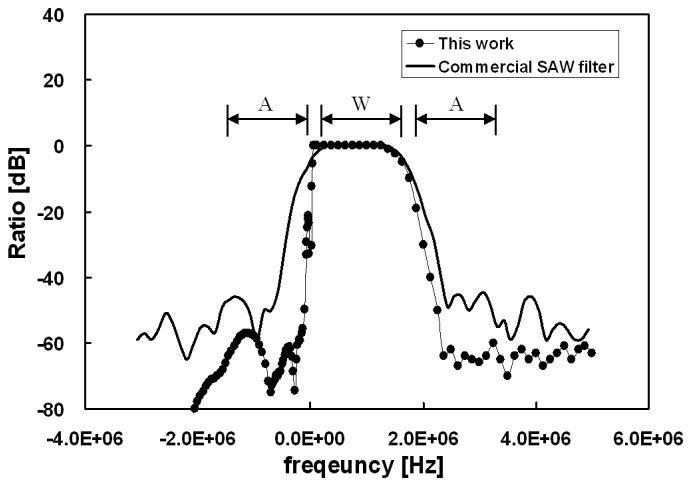

Figure 33.5.5: Comparison of IF response of this work and commercial IF SAW filter centered at 38.912 MHz. Center frequency of IF SAW filter is transformed for the purpose of comparison. W is wanted channel and A is adjacent channel.

	T-DMB / DAB		ISDB-T	
	Band-III	L-band	VHF	UHF
Noise figure (dB)	1.5	3.5	1.5	3
Power consumption (mW)	100	150	100	100~120
RF AGC range (dB)	70	60	70	70
IF AGC range (dB)	60	60	60	60
Sensitivity (dBm)	-101	-99	-99	-98
Max input power (dBm)	+10	+10	+10	+10
Digital ACR (dB)	40	35	35	37
Analog ACR (dB)	47	-	42	45
Faroff rejection (dB)	50	50	-	-

Figure 33.5.6: Performance summary of the tuner IC.

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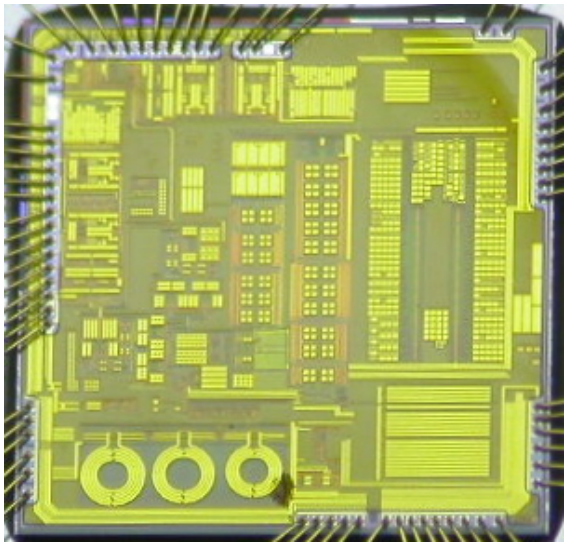

Figure 33.5.7: Micrograph of the tuner IC.

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